PREPARED IN COOPERATION WITH THE
COLORADO DEPARTMENT OF NATURAL RESOURCES, DIVISION OF WATER RESOURCES,
OFFICE OF THE STATE ENGINEER; THE DENVER BOARD OF WATER COMMISSIONERS;
AND ADAMS, ARAPAHOE, DOUGLAS, ELBERT, AND EL PASO COUNTIES

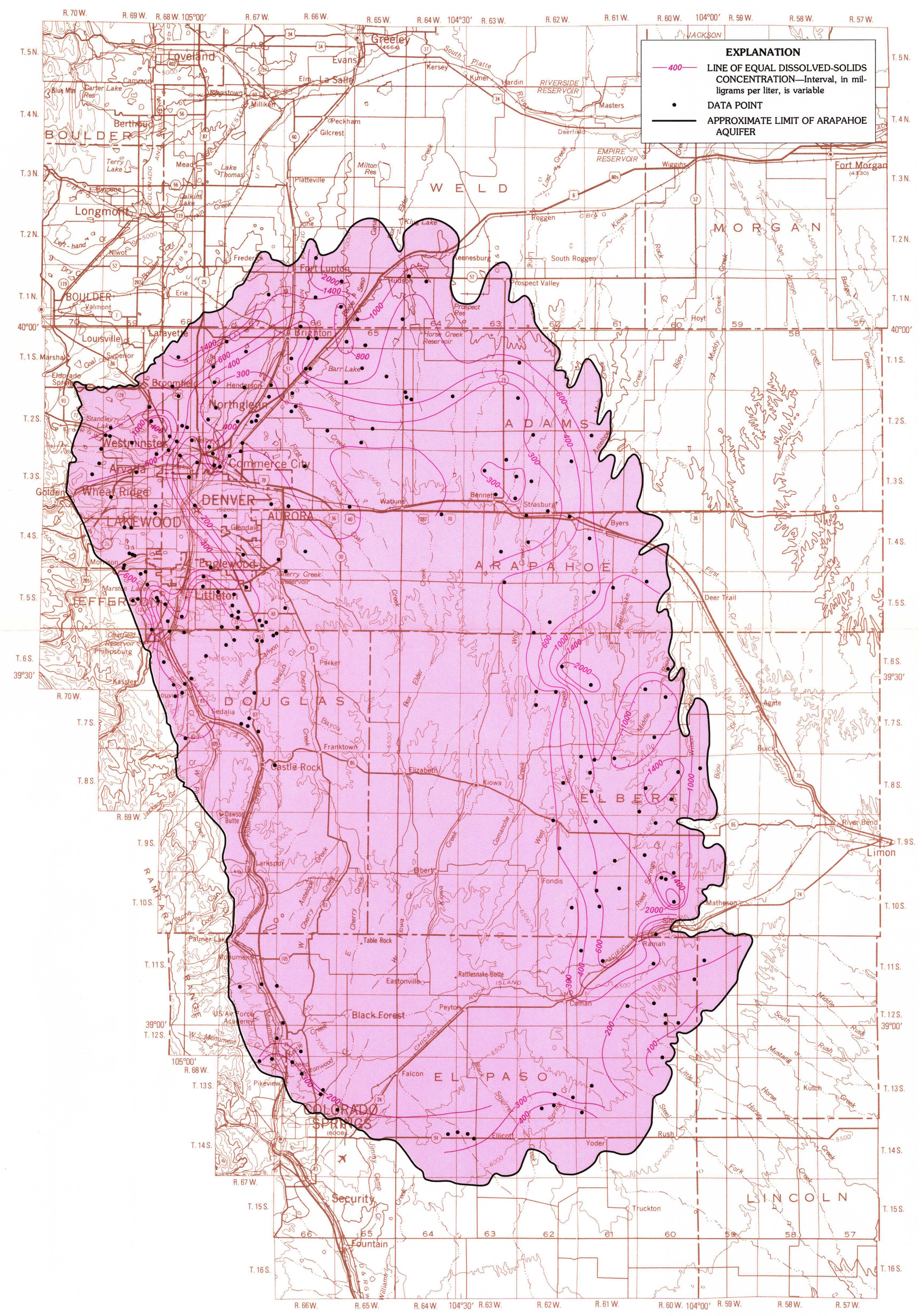

FIGURE 12.—MAP SHOWING DISSOLVED-SOLIDS CONCENTRATIONS OF WATER IN THE AQUIFER

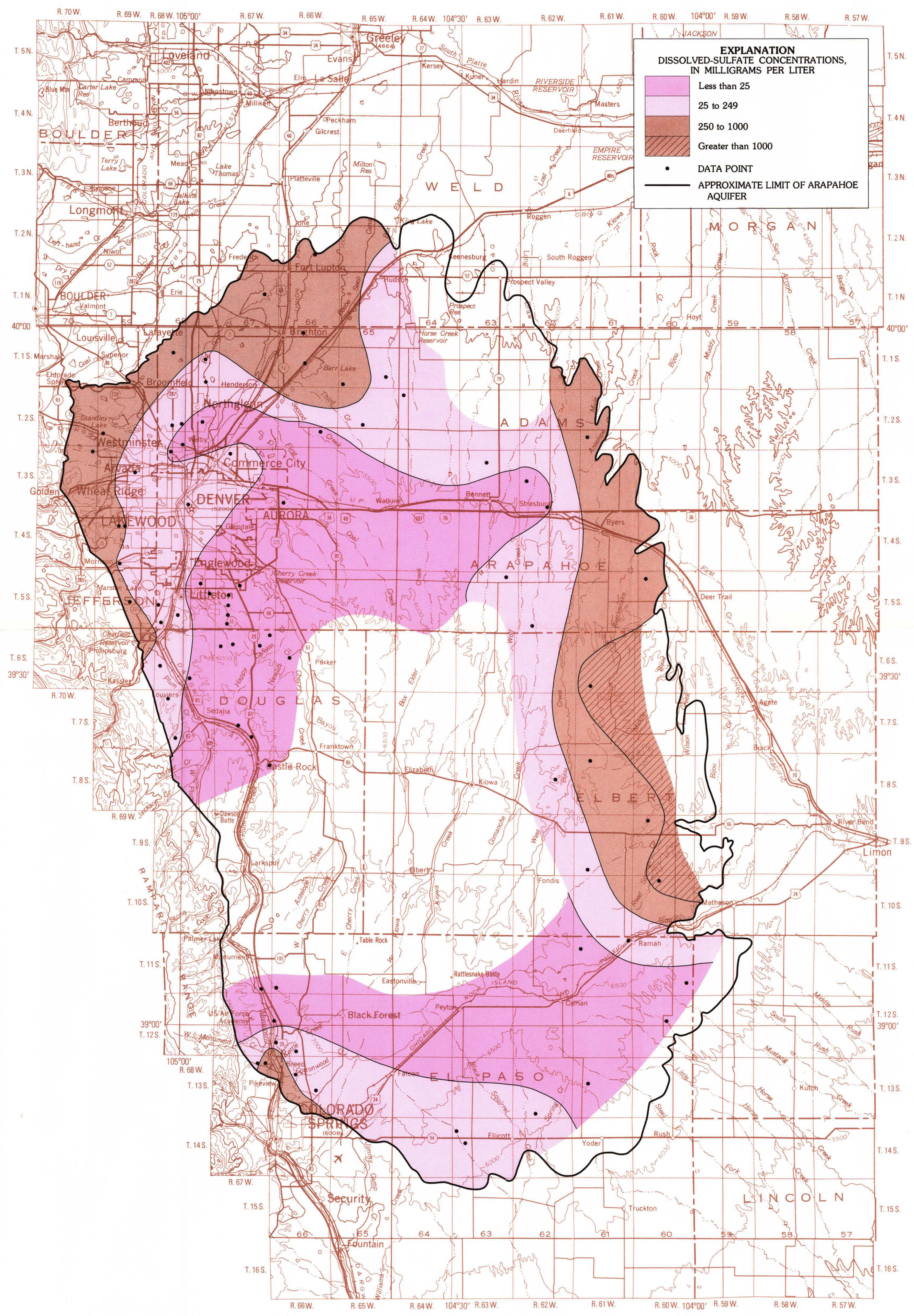

FIGURE 13.—MAP SHOWING DISSOLVED-SULFATE CONCENTRATIONS OF WATER IN THE AQUIFER

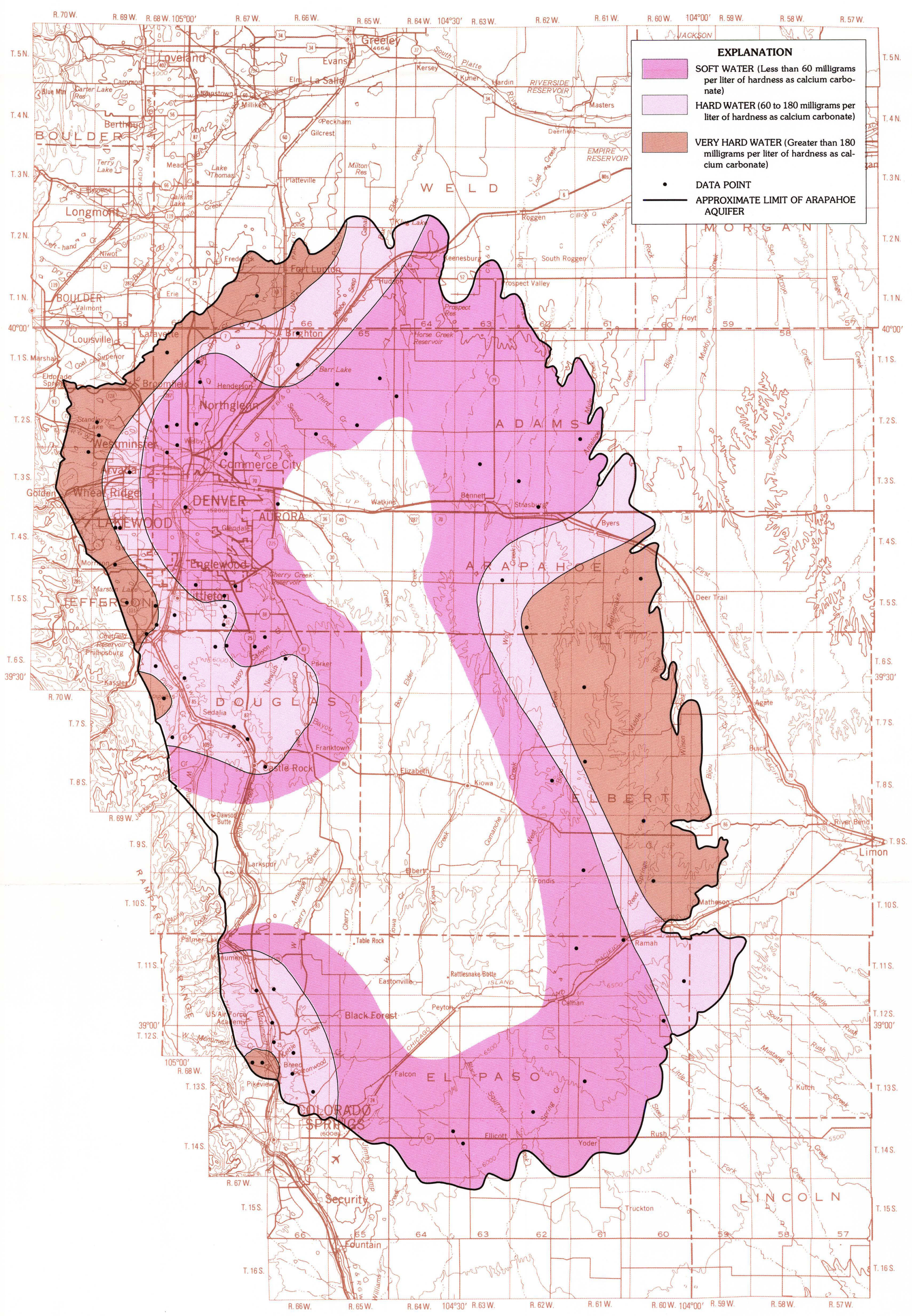

FIGURE 14.—MAP SHOWING HARDNESS OF WATER IN THE AQUIFER

WATER CHEMISTRY

Water in the Arapahoe aquifer is generally of good chemical quality, meeting drinking-water standards (Colorado Department of Health, 1978; U.S. Environmental Protection Agency, 1976, 1977) for public water supplies in most of the area. The water generally contains a preponderance of dissolved-sodium and bicarbonate ions and is classified as a sodium bicarbonate type water. Calcium bicarbonate type water also occurs in the aquifer at scattered locations and in the area between Sedalia and Colorado Springs. Water in the Arapahoe aquifer is generally similar in type to that found in the overlying Denver aquifer, possibly due to the downward movement of water from the Denver aquifer to the Arapahoe aquifer. Part of the precipitation that falls on the outcrop area percolates to depth carrying some of the soluble minerals from the soil and weathered bedrock into the aquifer. This process produces the sodium sulfate type ground water found in some areas near the margins of the aquifer.

The concentration of dissolved solids in ground water is a measure of the total mineral content of the water. Dissolved-solids concentrations of water in the Arapahoe aquifer are less in the central part of the aquifer, near the source of recharge from the overlying Denver aquifer. The concentrations of dissolved solids increase to more than 2,000 milligrams per liter in some areas as the water moves toward the margins of the aquifer, as shown on the accompanying map (fig. 12). This occurs as the result of soluble minerals being carried into the aquifer from near-surface sources and also seems to be affected by the thickness of the aquifer. As the aquifer becomes thinner near the edge, poorer quality water percolating from the surface has smaller quantities of better quality ground water available for dilution, resulting in ground water with larger dissolved-solids concentrations in areas where the aquifer is thinner.

The trough in the potentiometric surface along the South Platte River separates an area west of the river, where ground water contains relatively large dissolved-solids concentrations, from an area east of the river, where ground water contains relatively small dissolved-solids concentrations. These differences in water quality occur because the water in the Arapahoe aquifer west of the river is derived primarily from water percolating from the land surface through the outcrops of the Denver and Arapahoe Formations into the aquifer. Water in the aquifer east of the river is derived primarily from the deeper central part of the basin, where the water is less affected by near-surface sources of degradation.

Organic material present in the bedrock formations in the Denver basin alters the chemistry of the ground water by decreasing the availability of dissolved oxygen in the water. In an oxygen-deficient (reducing) environment, such as occurs in the Arapahoe aquifer, iron, which is normally relatively insoluble, can be dissolved and transported with the flowing ground water. When this water is pumped from a well and exposed to oxygen in the air, the dissolved iron reverts to an insoluble form that is visible as a black to reddish-brown precipitate, which clouds and discolors the water and stains porcelain fixtures and laundry. Although iron is present in the water throughout the aquifer, the severity of the problem varies considerably from well to well, apparently in response to the chemical environment in the local area. Dissolved-iron concentrations generally ranged from 20 to 200 micrograms per liter, which is less than the limit of 300 micrograms per liter recommended for public water supplies (U.S. Environmental Protection Agency, 1977). Dissolved-iron concentrations as much as 6,500 micrograms per liter occurred in water from a few widely scattered wells. In areas of strong reducing conditions in the aquifer, sulfate minerals and organic material may be reduced to hydrogen sulfide and methane gases. When these gases are present in high concentrations, water pumped from the aquifer may effervesce, have a putrid odor, and be of marginal value for many uses.

Dissolved-sulfate concentrations in excess of 250 milligrams per liter occur in a 500-square-mile area along the east margin of the aquifer and in a 350-square-mile area along the northwest margin of the aquifer (fig. 13). The U.S. Environmental Protection Agency (1977) recommends that dissolved-sulfate concentrations not exceed 250 milligrams per liter in public water supplies because of the laxative effect this compound can have on people unaccustomed to drinking the water. Measured concentrations of dissolved sulfate ranged from 5 milligrams per liter in the southeast part of the aquifer to as much as 1,500 milligrams per liter near the northern margin of the aquifer.

Hardness also may affect the acceptability of water for domestic use. Hard water is objectionable because it leaves scaly deposits on the inside of pipes, steam boilers, and hot water heaters, requires more soap to make a good lather, and roughens washed clothes and hands. The U.S. Geological Survey classifies hardness in terms of calcium carbonate as shown on the explanation of the map of ground-water hardness (fig. 14). Soft water occurs in most of the central part of the aquifer with hard and very hard water occurring near the northwest and east margins of the aquifer.

If specific water-quality information is required at a particular well site, it is often necessary to make a chemical analysis of a water sample. Because this can be time consuming and costly, it is helpfull to be able to estimate the concentrations of some dissolved constituents from the value of one easily measured constituent. Chemical analyses of water samples from about 80 wells indicate that reasonable estimates of dissolved-solids, alkalinity, bicarbonate, sodium plus calcium, and sulfate concentrations can be made when the specific conductance of the water sample is measured. These relations are shown in the adjacent graphs (fig. 15). The graph showing the sodium plus calcium, specific conductance, and sulfate relations applies to all the ground water in the Arapahoe aquifer while the two remaining graphs apply only to sulfate type water or bicarbonate type water as indicated. Sulfate type water generally occurs in those areas with more than 250 milligrams per liter dissolved sulfate as shown on the map of dissolved-sulfate concentrations (fig. 13). Ground water in areas with less than 250 milligrams per liter sulfate is generally a bicarbonate type water.

As an example of how these graphs can be used, a well at Brighton would have about 400 milligrams per liter dissolved solids (as read from the dissolved-solids-concentration map) and be located in an area of sulfate type ground water (as shown on the sulfate-concentration map). The 400 milligrams per liter dissolved-solids line crosses the sodium and calcium line at about 130 milligrams per liter, crosses the specific-conductance line at 600 micromhos, and crosses the sulfate line at 100 milligrams per liter. These are the sodium plus calcium concentration, specific conductance, and sulfate concentration that would likely be found in the Arapahoe aquifer near Brighton. Because the water in this area is of a sulfate type, the second graph indicates that bicarbonate concentrations would be about 150 milligrams per liter and alkalinity would be about 100 milligrams per liter.

USE OF THE MAPS

The maps presented in this report are intended to provide a general understanding of the hydrologic and geologic conditions in the Arapahoe aquifer and to provide specific information useful in developing and using the water. Those readers who may be unfamiliar with hydrologic and geologic maps may wish to consider the following examples which illustrate how the maps can be used to evaluate the water supply in different areas of the Arapahoe aquifer. In addition to comparing areas within the same aquifer, it is also possible to use these maps with other data (Robson and Romero, 1981) to compare the water-supply potential in different bedrock aquifers. The calculated values are referenced by letter to the corresponding letter shown on the adjacent diagram (fig. 16) and the computations are shown in table 1. Two sites are considered as examples—one at Aurora, the other at Brighton. The land-surface elevations can be estimated from the topographic contours shown on the adjacent maps or from U.S. Geological Survey 7½-minute topographic-quadrangle maps. The land-surface elevation is about 5,400 feet at Aurora and is about 5,000 feet at Brighton.

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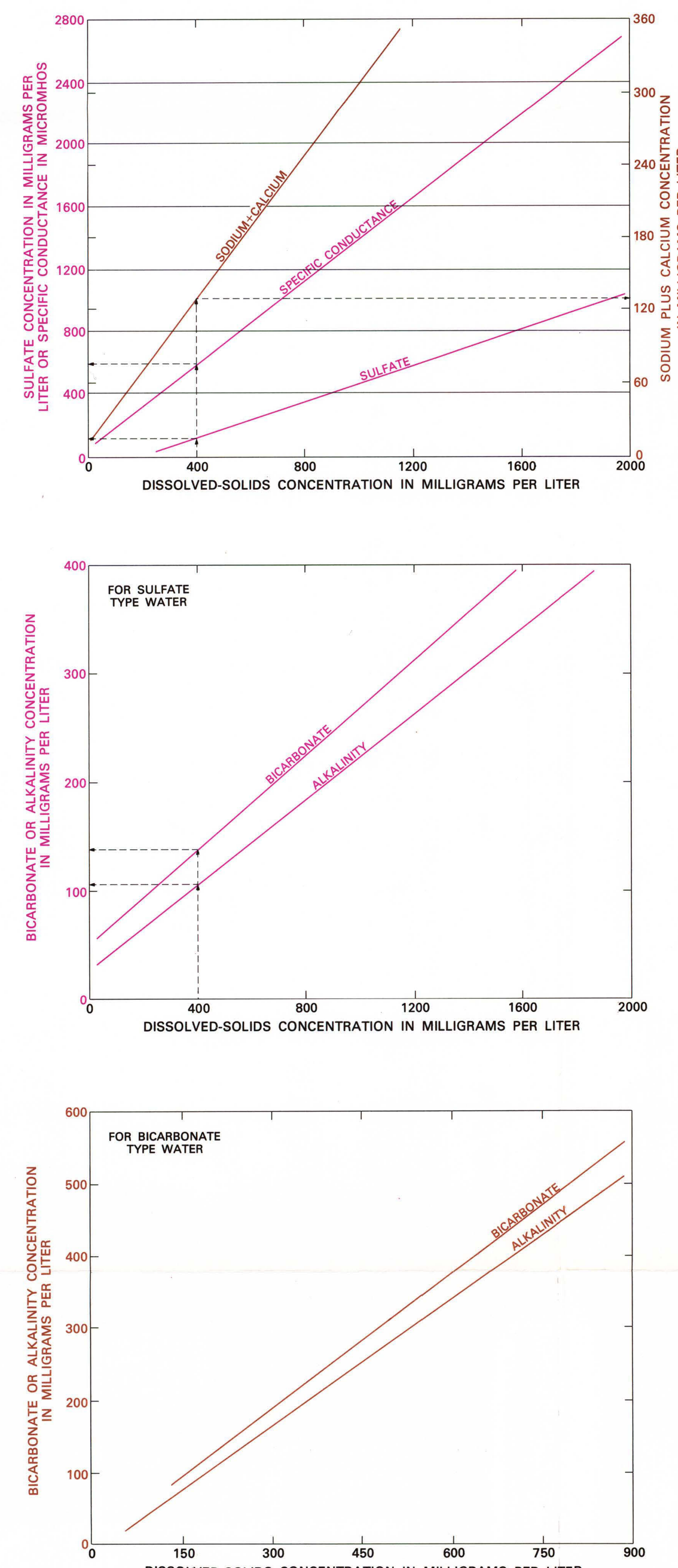
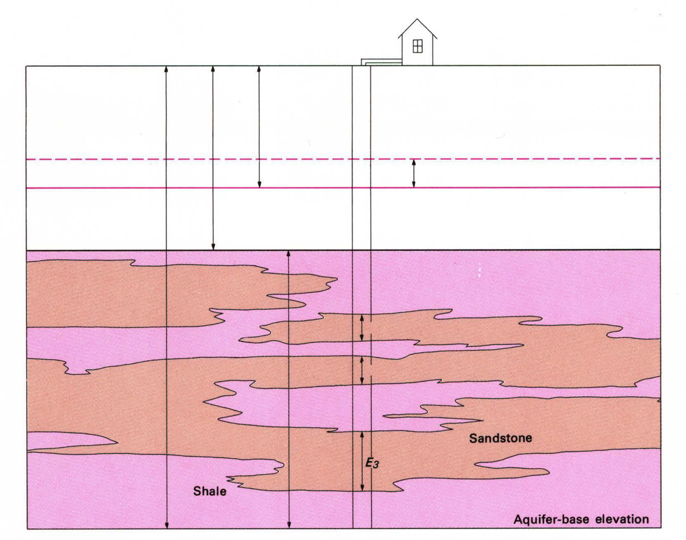


FIGURE 15.—GRAPHS SHOWING WATER QUALITY RELATIONS

The information summarized in table 1 can be used to evaluate the water supply available from the Arapahoe aquifer at each site. The Arapahoe aquifer at Aurora has a greater depth to water and is thicker and more deeply buried than the aquifer at Brighton. The greater depth to water at Aurora will require more energy to lift the water to the land surface and pumping costs consequently will be higher. If water levels near Aurora continue to rise, future pumping lifts could be reduced, while the pumping lifts at Brighton would increase if water-level declines continue in that area. Although the aquifer at both locations contains an equal thickness of conglomerate and sandstone, the aquifer at Aurora can sustain a greater drawdown without affecting the thickness of the aquifer. Thus, if the aquifer is equally permeable in both areas, the aquifer at Aurora could yield more water than the aquifer at Brighton.

The chemical quality of the water at Aurora is slightly better than that at Brighton. Dissolved-solids concentrations of about 200 milligrams per liter occur near Aurora and concentration of about 400 milligrams per liter occur at Brighton. The water at Aurora is soft while that at Brighton is hard. Dissolved-sulfate concentrations are less than 25 milligrams per liter at Aurora and between 25 and 250 milligrams per liter at Brighton.



EXPLANATION

A. Depth to base of aquifer
B. Depth to top of aquifer
C. Depth to water in 1978
D. Aquifer thickness
E. Sandstone thickness, total=$E_1+E_2+E_3$
F. 1958–to–1978 water-level change

FIGURE 16.—DIAGRAM SHOWING COMPUTED QUANTITIES

Table 1.—Summary of computations (in feet)

	Aurora	Brighton
A. Depth to base of aquifer:		
Land-surface elevation	5,400	5,000
Aquifer-base elevation	4,230	4,590
Difference	1,170	410
B. Depth to top of aqufier:		
Land-surface elevation	5,400	5,000
Potentiometric-surface elevation		4,890
Aquifer-top elevation	4,740	
Difference	660	110
C. Depth to water:		
Land-surface elevation	5,400	5,000
Potentiometric-surface elevation	5,060	4,890
Difference	340	110
D. Aquifer thickness:		
Potentiometric-surface elevation		4,890
Aquifer-top elevation	4,740	
Aquifer-base elevation	4,230	4,590
Difference	510	300
E. Sandstone and siltone thickness read directly from map	160	160
F. Water-level change, from 1958 to 1978, read directly from map	25(rise)	50(decline)

A. The depth to the base of the aquifer is the difference between the land-surface elevation and the elevation of the base of the aquifer. The depth to the base of the Arapahoe aquifer is 1,170 feet at Aurora and 410 feet at Brighton. These values are in close agreement with those shown on the map of depth to the base of the aquifer.

B. The depth to the top of the aquifer is calculated in one of two ways depending on the location of the site. Aurora is not located in the partially saturated zone, so the depth to the top of the aquifer is the difference between the land-surface elevation and the elevation of the top of the aquifer. Brighton, however, is located in the partially saturated zone, so the depth to the top of the aquifer here is the difference between the land-surface elevation and the elevation of the potentiometric surface. The depth to the top of the Arapahoe aquifer is 660 feet at Aurora and 110 feet at Brighton.

C. The depth to water in a well is the difference between the land-surface elevation and the elevation of the potentiometric surface. During 1978 the depth to water in a well completed in the Arapahoe aquifer was 340 feet at Aurora and 110 feet at Brighton.

D. The aquifer thickness also is calculated in one of two ways depending on the location of the site. At Aurora (not in the partially saturated zone) the aquifer thickness is the difference between the elevation of the top of the aquifer and the elevation of the base of the aquifer. At Brighton (in the partially saturated zone) the thickness of the aquifer is the difference between the elevation of the potentiometric surface and the elevation of the base of the aquifer. The Arapahoe aquifer is 510 feet thick at Aurora and 300 feet thick at Brighton.

E. The map showing total conglomerate, sandstone, and siltstone thickness indicates the thickness to be 160 feet at both Aurora and Brighton.

F. The water-level change between 1958 and 1978 is shown on the water-level change map. At Aurora the water level in the Arapahoe aquifer has risen about 25 feet while at Brighton about 50 feet of water-level decline has occurred.

Base from U.S. Geological Survey
State base map, 1969

SCALE 1:500 000
10 0 10 20 30 40 50 MILES
10 0 10 20 30 40 50 KILOMETERS
CONTOUR INTERVAL 500 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

GEOLOGIC STRUCTURE, HYDROLOGY, AND WATER QUALITY OF THE ARAPAHOE AQUIFER IN THE DENVER BASIN, COLORADO

By
S. G. Robson, U.S. Geological Survey, and John C. Romero and Stanley Zawistowski, Colorado Division of Water Resources

1981